Overview of Explosives Detection Research and Development in Department 5848 at Sandia National Laboratories

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Abstract

This paper provides an overview of work performed during the past five years in the area of explosives detection in the Contraband Detection Technologies department at Sandia National Laboratories. Broadly speaking, this work falls into two categories. First, the department has been in the forefront of developing trace detection technology for real-world applications. The basis for this technology has been a patented chemical preconcentrator that collects vapor and particles of explosives with high efficiency, prior to delivery into a chemical sensor. This preconcentrator has been used in several systems, most notably a personnel portal developed with primary funding from the Federal Aviation Administration. Second, the department serves as the main resource on explosives detection information for the United States Department of Energy (DOE), and has consulted and developed documents for other government agencies. One important aspect of this work is an on-going program of commercial equipment evaluation for the DOE. The paper concludes with a brief discussion of possible future directions.

Introduction

The Contraband Detection Technologies department at Sandia National Laboratories has for many years been involved in a variety of research and development projects related to the detection of explosives. The primary focus of this work has been trace detection, i.e. the detection and identification of explosives via collection of either vapor or microscopic particle contamination. This paper covers the most important accomplishments in this area during the last five years. Work has been performed for a number of sponsors during this period, including the Federal Aviation Administration (FAA), Department of Energy Office of Safeguards and Security (DOE OSS), the Technical Support Working Group (TSWG), the Nuclear Emergency Search Team/Joint Technical Operations Team (NEST/JTOT), the National Institute of Justice (NIJ), the National Law Enforcement and Corrections Technology Center (NLECTC) Rocky Mountain Region, the National Institute of Standards and Technology Office of Law Enforcement Standards (NIST OLES), and the Federal Bureau of Investigation (FBI).

Sandia Screen Preconcentrator

The heart of most detection systems that have been developed in the group during the past five years is the Sandia screen preconcentrator (SSP). In detecting explosives vapor or particles with a trace detector such as an ion mobility spectrometer (IMS) in a real-world setting, it is often difficult to (a) collect enough trace sample for the detector to make a positive identification, and (b) effectively transport this sample to the detector. The entire process is subject to throughput constraints, i.e. it is often necessary to screen a large number of items in a very limited amount of time. The patented SSP [1] addresses these problems via rapid and efficient collection of air-borne explosives material. A photo of the SSP is shown in Figure 1, and Figure 2 provides a schematic representation of how it functions. A large volume of air is pulled into the SSP, where it passes through a high density metal screen. The screen traps heavy organic molecules such as explosives with an efficiency near 50%, whether these species are in the form of vapor or particles. After the incident air flow has passed through the SSP, a small volume around the screen is isolated, and the screen is rapidly heated to ca. 200 °C to desorb any collected explosive material back into the gas phase. A much smaller air flow, perpendicular in direction to the original incoming air flow (and parallel to the screen face), is then used to pulse the desorbed material into a chemical sensor. This process allows the explosive material from a large air volume to be concentrated by a factor of 100-1000 before it is introduced into a detector, thus

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dramatically increasing the probability of detection. While the process has been developed for explosives, the SSP should in principle work for other heavy organic molecules as well. Recent work funded by NIST OLES has shown this method of concentration to be effective for certain illicit drugs [2].

Sandia/FAA/Barringer Personnel Portal

The single largest project undertaken by the group during the past five years has been the development of a walk-through portal that uses trace detection to screen personnel for explosives. Developed with principal funding from the FAA, this patented portal [3] was

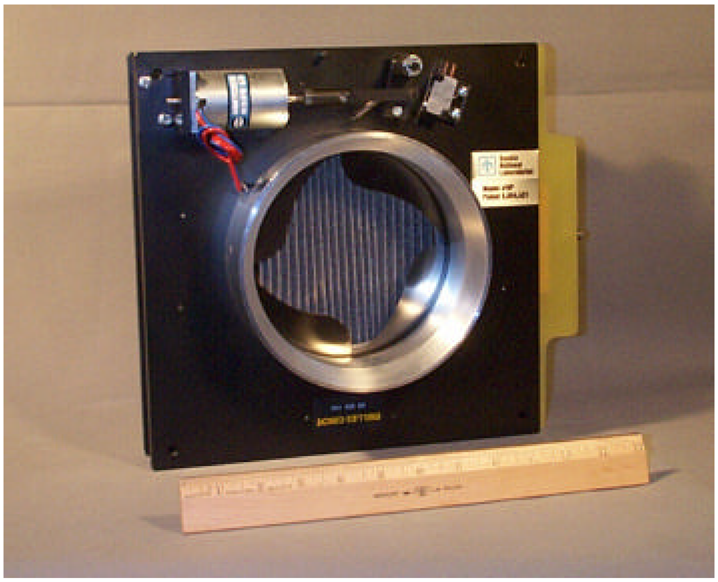

Figure1. The Sandia screen preconcentrator. Sampled air enters through the large round opening, and explosives molecules/particles are adsorbed on the pleated screen.

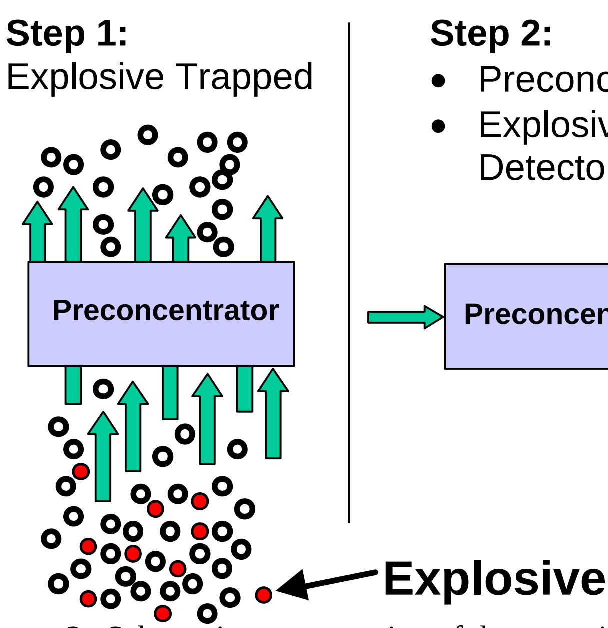

Figure 2. Schematic representation of the operation of the screen preconcentrator.

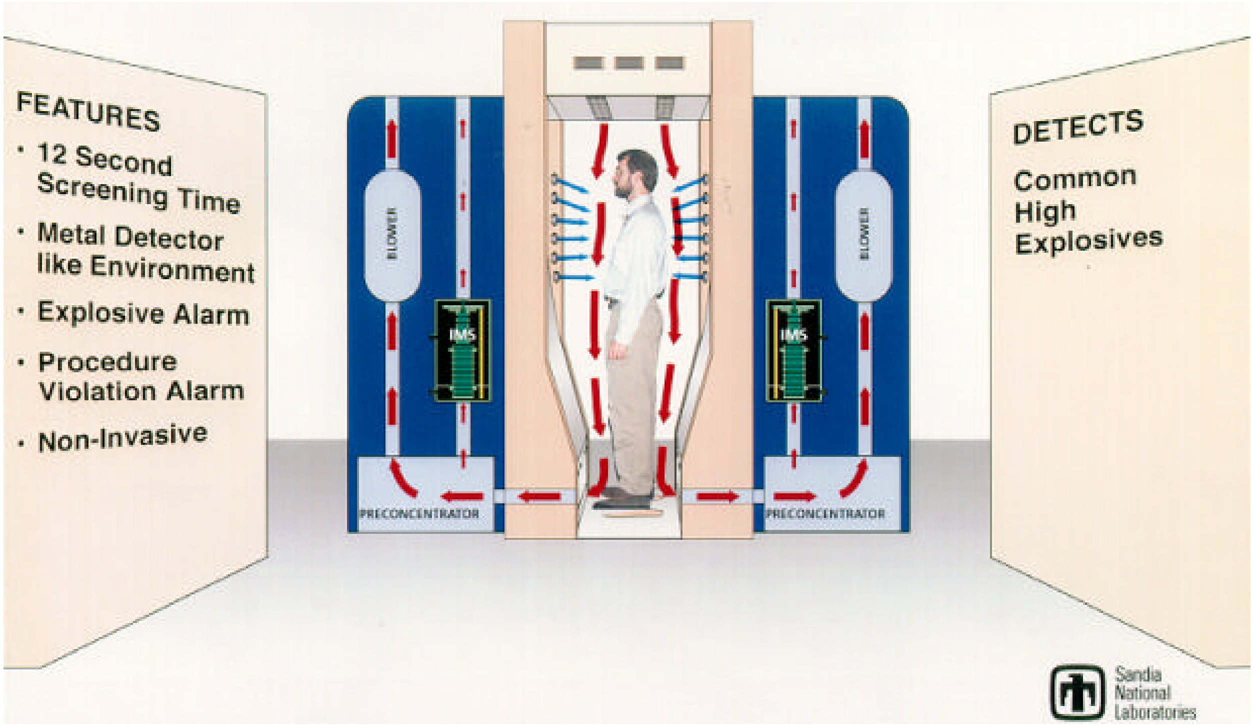

Figure 3. Schematic representation of the Sandia explosives detection portal

designed to screen personnel in airport terminals, necessitating a throughput rate comparable to the ten persons/minute typical of airport metal detection portals. A schematic representation of the portal is shown in Figure 3. Air flows downward from the top of the portal along the body of a test subject, and is then pulled into two slots at the bottom at a rate of 160 liters/second. Air jet nozzles mounted in the sides of the portal are used to agitate the person's clothing, to dislodge any particulate contamination that may be present. The air flow with any entrained explosives vapor or particles then passes through a SSP, and after collection of the explosive material on the screen it is delivered to an IMS detector as described above. The portal has undergone extensive laboratory testing, demonstrating sensitivity to sub-fingerprint amounts of key high explosives under many circumstances. In airport testing performed at the Albuquerque airport in September, 1997, 2400 persons were screened with a false alarm rate below 1%, and a measured throughput rate of five persons/minute. A blind detection of trace explosive material was also made on a worker from the nuclear weapons complex. Additional improvements are being incorporated into the portal, most notably a change in design resulting in the use of only a single detection module rather than two. The portal technology has been licensed to Barringer Instruments, Inc. [4], and the portal should be commercially available sometime before the end of 2000.

Sandia/TSWG/DOE Vehicle Portal

Another major project, running through fiscal years 1999-2001, is the development of a portal for screening vehicles based on similar trace detection technology. A photograph of the first breadboard vehicle screening module is shown in Figure 4. Like the personnel portal, this module contains a blower for generating large air flows, a SSP, and a commercially available IMS. It is designed to fit snugly against a particular vehicle, but this design will eventually be generalized so that it can be used to screen vehicles of different sizes and shapes. As with the personnel portal, this system will detect both vapor and particle contamination, and the detection of fingerprints on the exterior of a vehicle has already been demonstrated for several key explosives. The portal eventually developed will consist of multiple modules of this type, screening different parts of a vehicle. Field testing of a completed prototype will occur during fiscal year 2001, and if possible commercialization of the vehicle portal will be pursued simultaneously.

Figure 4. Prototype module for screening vehicles for explosives.

Man-Portable Systems

Development of man-portable systems employing the SSP technology has also been pursued. Funded by DOE OSS, NEST/JTOT, and the FBI, this work has involved coupling a miniaturized version of the SSP with commercially available hand-held trace detectors. An example of such a detector is the Ion Track Instruments VaporTracer [5], and Figure 5 shows a photo of a system incorporating this detector and the miniaturized preconcentrator. The preconcentrator controls are contained in a backpack, so that the total system can be easily transported by one person. As with the personnel portal, the addition of a SSP on the front end allows the rate of air sampling by a hand-held detector to be increased dramatically, from ca. one liter/minute to ca. 100 liters/minute. This allows for more efficient sampling of vapor from explosives with very low vapor pressures, and for any type of explosive it allows the sampling end of the instrument to be further from the explosive during sampling.

Additional Research and Development Work

Research has also been pursued in other areas. Like all detectors, IMS detectors have shortcomings as well as strengths, and for this reason adapting the preconcentration technology to other types of trace detectors is of interest. We are currently collaborating with Syagen Technology, Inc.[6], to adapt this technology to use with their mass spectrometer. Since the material present on the surface of the preconcentrator screen should be important in the adsorption and desorption of analyte molecules, we are also investigating the effects of different screen coating materials on SSP performance. As stated above, some preliminary work has also been performed in the area of drug detection.

Document Development for Law Enforcement Applications

During the past three years, department 5848 has also written several reference documents on trace detection for different law enforcement organizations. The first such document, entitled "Survey of Commercially Available Explosives Detection Technologies and Equipment" [7], was published by the National Institute of Justice in 1998, after its development was funded through the National Law Enforcement and Corrections Technology Center (NLECTC), Rocky Mountain Region. This document provides a broad overview of the different types of explosives detection currently available, including trace, canine, x-ray, nuclear methods, and physical search. It also contains contact information on companies marketing specific systems, and an

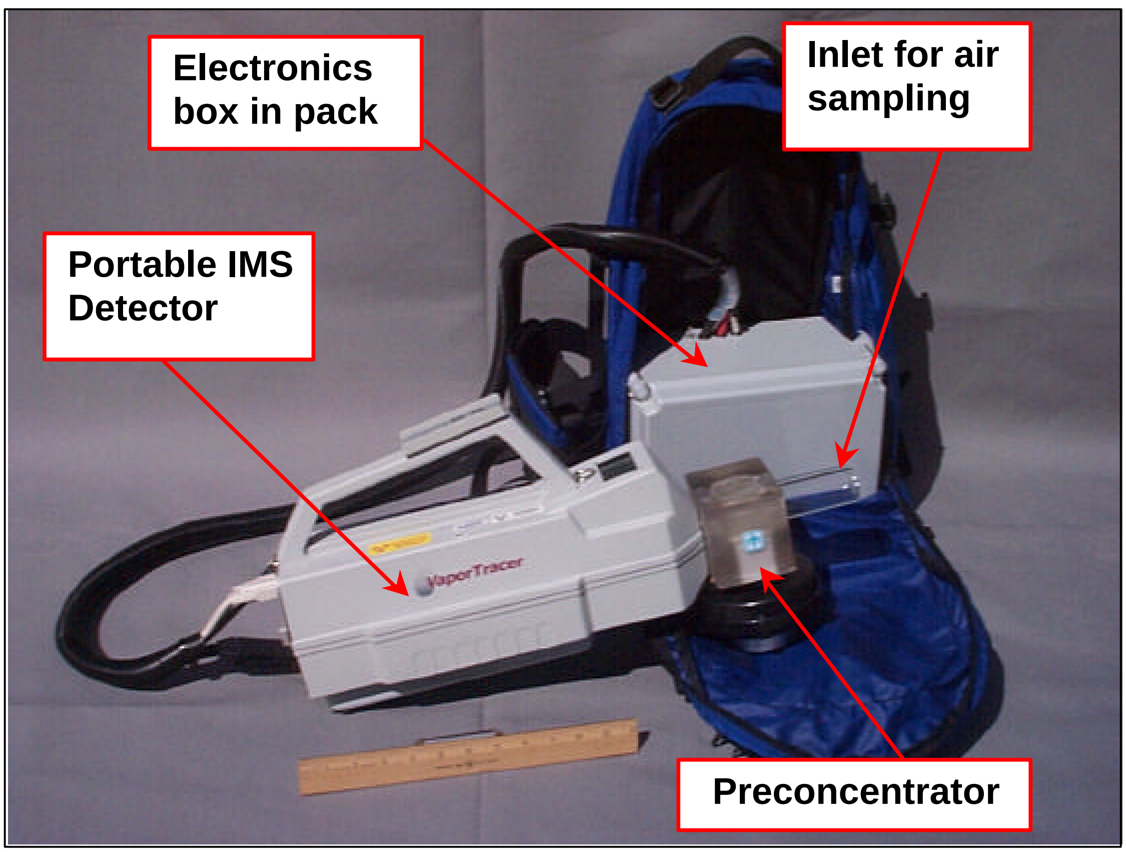

Figure 5. Man-portable system for explosives detection, incorporating a miniaturized version of the Sandia screen preconcentrator

extensive appendix with basic information about explosives and explosions. This document has gone through two printings, with several thousand copies having been distributed. A follow-up document, "Guide for the Selection of Commercial Explosives Detection Systems for Law Enforcement Applications" [8], was subsequently funded by NIST OLES, and was published in 1999. This document provides much more extensive information aimed at assisting agencies in selection of specific detection systems. Finally, a document surveying commercially available drug detection technologies has also been funded by NIST OLES [9], and will be published in the near future.

Evaluation of Commercial Detectors for DOE

A final area of research has been the evaluation of commercially available trace detection systems for DOE OSS. Geared towards providing information for DOE sites that might purchase detection equipment, this work has been on-going for over five years. Table I contains a list of the trace systems that have been tested. We have recently begun to perform some evaluations of bulk systems as well. The testing is performed according to a standard test protocol, with an emphasis on critical test parameters such as probability of detection, limits of detection, and false alarm rates. Detailed test reports have been written for most of these systems, and these reports may be requested from OSS by government organizations with the need to access such information.

Manufacturer	Trace Detection System(s)
Thermedics Detection	EGIS 3000
Intelligent Detection Systems	EVD-3000
Ion Track Instruments	VIXEN, Model 97 VIPER, VaporTracer, ITEMISER, EntryScan Model 85
Barringer Instruments	IONSCAN 350, IONSCAN 400B
Graseby Security	Plastec

Table I. Trace detection systems evaluated at Sandia National Laboratories

Summary and Future Directions

Much of the work discussed in this paper will continue in the near future. Department 5848 at Sandia National Laboratories is happy to assist government agencies with a need to know to obtain information on any of this work. We are also happy to hold discussions with private companies with regards to possible future work. Potential areas of collaboration include the following:

(1) Development of novel technologies for explosives detection: If a company has a technology that they believe is new and promising, or has simply been underutilized in the area of explosives detection, joint R&D efforts aimed at moving towards a marketable product may be possible.

(2) Detection of drugs and other classes of compounds: Since our basic preconcentrator/IMS detection scheme should work for compounds other than explosives, we are eager to further investigate the detection of illicit drugs and other compounds that may be of interest/concern.

(3) Development of dual technology systems: In many cases, explosives screening systems will work best if trace detection is combined with another technology, such as bulk detection based on x-ray imaging or a nuclear technique. Joint projects with companies having expertise in these techniques are needed to produce such dual technology systems.

(4) Evaluation of commercial systems: We will continue to perform evaluation of new market entries for DOE OSS, so we are glad to have promising new systems brought to our attention for this purpose. Since it is generally not possible to test every new detector that comes to market, the decision on which systems to test will be based on discussions with the funding agency.

Acknowledgments

We again thank the various agencies, organizations, and centers that have funded the work discussed in this paper: FAA, DOE OSS, TSWG, NEST/JTOT, NIJ, NLECTC Rocky Mountain Region, NIST OLES, and FBI. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

References

[1] U. S. Patent number 5,854,431.
[2] “Final Report on Trace Detection of Narcotics using a Preconcentrator/Ion Mobility Spectrometer System”, J. E. Parmeter, G. A. Eiceman, and J. E. Rodriguez, submitted to the National Institute of Standards Office of Law Enforcement Standards, September, 1999.
[3] U. S. Patent number 5,915,268.
[4] Barringer Instruments, 30 Technology Drive, Warren, NJ, 07059, (908) 222-1557.
[5] Ion Track Instruments, 205 Lowell Street, Wilmington, MA, 01887, (978) 658-3767.
[6] Syagen Technology, Inc., 1411 Warner Ave, Tustin, CA. 92780, (714) 258-4400.
[7] “Survey of Commercially Available Explosives Detection Technologies and Equipment”, D. W. Hannum and J. E. Parmeter, National Law Enforcement and Corrections Technology Center, National Institute of Justice, September, 1998.
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